BIOSIGNAL ACQUISITION AND INTERFACING TECHNIQUE FOR POST STROKE REHABILITATION

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For my lovely parents, family and fellow friends.

Thank you for your continuous support.

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"All the praises and thanks be to Allah SWT, who has guided us to this, never could we have found guidance, were it not that Allah SWT had guided us!" (Al-Araf: Verse 43)

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ABSTRACT

This thesis presented a wireless monitoring system which consist of data logging function for hand movement related both to sportsman and patient. The system which comprised of the application of gyroscope and accelerometer sensor was tested on healthy normal subject for the initial proof of concept. The subject was needed to wear a set of sensors over the wrist while performing few basic arm movements. The study focused on designing, developing and simulating the experimental results. The recorded result can be used for the purpose of post-processing and progressive status tracking. The data was saved into a microSD card for further analysing purposes. The system was then used for different application with the addition of tilt sensors. The subject was required to wear a set of sensors over the palm with the basic arm movements during the experiment. The experiment demonstrated the capabilities of the sensors to produce the extended information and also the Android applications in responding to the hand movement activities in real time. The results obtained from the experiments were presented in various graphical representations which showed the stability of the system in producing the consistence output. It offered more information with the ability to improve the training quality and also monitoring the progress of the sportsmen and post-stroke patients. Lastly, the interactive output developed would enable the users to keep track on their performance level and thus eventually, motivates them to continue successfully the training or therapy session.

ABSTRAK

Tesis ini membentangkan sistem pemantauan tanpa wayar yang terdiri daripada fungsi penyimpanan data untuk pergerakan tangan yang berkaitan dengan olahragawan dan pesakit. Sistem yang terdiri daripada penggunaan gyroscope dan sensor accelerometer telah diuji pada subjek normal yang sihat untuk bukti awal konsep. Subjek perlu memakai satu set sensor pada pergelangan tangan semasa melakukan beberapa gerakan lengan asas. Kajian ini memberi tumpuan kepada merekabentuk, membangun dan mensimulasikan keputusan percubaan. Hasil yang direkodkan boleh digunakan untuk tujuan pemprosesan pasca-pemprosesan dan pengesanan status progresif. Data telah disimpan ke dalam kad microSD untuk tujuan analisa selanjutnya. Sistem ini telah digunakan untuk aplikasi yang berbeza dengan penambahan sensor kecondongan. Subjek perlu memakai satu set sensor ke atas tapak tangan dengan pergerakan lengan asas semasa eksperimen. Percubaan menunjukkan keupayaan sensor untuk menghasilkan maklumat lanjutan dan juga aplikasi Android dalam terhadap tindak balas aktiviti pergerakan tangan pada masa sebenar. Keputusan yang diperoleh daripada eksperimen dibentangkan dalam pelbagai gambaran grafik yang menunjukkan kestabilan sistem dalam menghasilkan keluaran yang konsistensi. Ia menawarkan lebih banyak maklumat dengan keupayaan untuk meningkatkan kualiti latihan dan juga memantau kemajuan olahragawan dan pesakit pasca-strok. Akhir sekali, output interaktif yang dibangunkan membolehkan pengguna untuk mengesan tahap prestasi mereka dan dengan itu akhirnya mendorong mereka untuk meneruskan sesi latihan atau terapi dengan jayanya.

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LIST OF SYMBOLS AND ABBREVIATIONS

AAROM	-	Active Assisted Range of Motion
ADC	-	Analog to Digital Converter
API	-	Application Programming Interface
APS	-	Application Support Sublayer
AROM	-	Active Range of Motion
AVD	-	Android Virtual Interface
B4A	-	Basic4Android
CMOS	-	Complementary Metal-Oxide Semiconductor
EDR	-	Enhanced Data Rate
GPRS	-	General Packet Radio Service
GPS	-	Global Positioning System
GUI	-	Graphical User Interface
GSM	-	Global System for Module
I2C	-	Inter-Integrated Circuit
IDE	-	Integrated Development Environment
KHz	-	Kilohertz
LED	-	Light Emitting Diode
MEMs	-	Micro-Electro-Mechanical Systems
MHz	-	Megahertz
NMEA	-	National Marine Electronics Association
PROM	-	Passive Range of Motion
RAD	-	Rapid Application Development
SD	-	Secure Digital
SIM	-	Subscriber Identification Module
SPI	-	Serial Peripheral Interface
SRAM	-	Static Random-Access Memory

TCPIP	-	Transmission Control Protocol over Internet Protocol
WSN	-	Wireless Sensor Networks
wDAQ	-	Wireless Data Acquisition

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

The purpose of this chapter is to present the initial related matters to the development of this project with regard to Micro-Electro-Mechanical Systems (MEMs) for motion analysis in rehabilitation process system and application in sports science. It is a wearable device that captures various raw linear positional data based on the action or movement from the rehabilitation exercises. This low-cost and mobile monitoring device is designed specifically for post stroke patient who needs to analyse his or her performance during the rehabilitation process.

The motivation for this work is derived from the rehabilitation of post stroke patient especially in Malaysia. Stroke patient mainly consist of elderly patient and population may need extra care and training for recovery process. Often the recovery process are only monitored as the event happens that means when the patient undergo specific training program. Post-stroke rehabilitation is required for the patient to regain back their mobility thus can precede with their daily life activities. Post-stroke patient initially will lose their fitness and therefore they are also affected sometime to the extent of mental disturbance. The patient tends to be demotivated since unable to see their performance while undergoing the rehabilitation training.

Thus, patient will require self-motivation in order to complete the whole training programs which normally each program for rehab requires from 2 to 4 months minimum. Maximum training can go up to 6 months to a year. Despite the patient own enthusiasm in completing the rehabilitation process, motivational support from

caregivers, family and friend are also essential to help the patient advancement in recovery process.

Many institution and researches are actively finding ways on how to help the post stroke patient to undergo successful rehabilitation exercise program (Rahman and Al-Jumaily and Adel, 2013, Serder et al., 2017). Recent advancement in wearable sensor technology has made big impact for stroke patient since there are so many people happen to be affected by stroke every year (World-stroke 2016). The electronic technology-based rehabilitation system can help to monitor, interpret and analyze the data of all patterns obtained during the rehabilitation exercise done by the post stroke patients. The incorporation of high technology features such as Bluetooth and Wireless system does ease the process of rehabilitation (Emmanuel T., 2017). Gamification method was also adapted into the rehabilitation in order to increase the interest of patient to complete the rehabilitation process (Carlos F. et al, 2014).

Therefore, the project described in this work involved the application of several sensors incorporated as a whole system that can monitor the patient heeling performance. The system is later developed to log and document data measurement obtained from the sensors to be transmitted to a computer wirelessly. The system is compatibly linked between the hardware and software parts. In this study it is aimed to produce rehabilitation monitoring system which able to assist the post-stroke patient in gaining quantified results or values which can motivate them to further use the device for rehabilitation.

The system also comes with an extra function where it can capture and store the data as for future reference therefore it makes the system to be more interesting also for other application apart from rehabilitation which can be the data recoding for sport science performance. In sport science the athletes will require to understand a particular type of game structure and playing pattern by themselves or opponent therefore this system can also be useful for them to reevaluate their performance during a particular game session.

1.2 Problem Statement

It is a normal choice for years to apply local traditional medicine and medicine as the alternative treatment for post-stroke patients (Anuar H.M., 2012, Wu B. et al., 2007, Jamal J. A., 2007). The reasons behind this are that those medications are easy to reach,

relatively cheap, convenient and less hassle compared to the one provided in the hospital. There are several questions issued related to this matter especially on how to check the performance of the post stroke patient and effectiveness of the treatment.

The potential side effect produced by the herbs which are yet should be scientifically proven is another factor to be taken into consideration (Keat W.L. & Siew H.G., 2012). Other than that, the process for rehabilitation training provided at the training center often requires long period of consistence performance which also time consuming. The patient may also not know their percentage of improvements from the training session provided. This can be a problem in which patient will discontinue the training programs since unable to observe the improvement patterns from the undergone therapy. Thus, a cheap, small and robust wearable system is introduced. Today, inertial sensors for movement detection and tracking are inexpensive, small and require very little power, making them highly attractive especially in rehabilitation activities. Among the advantages of applying Android technology in this project is the ability for the system to allow different people to simultaneously share the same application. Another benefit is the analyzed data can be accessed throughout the world. Overall the developed system will enable the patient to use the system for monitoring their rehabilitation process by capturing the data and storing for future reference.

1.3 Aim and Objectives of The Research

1.3.1 Aim

The aim of the project is to develop a rehabilitation process system for post stroke patient. The system includes design of a monitoring system using gyroscope and accelerometer sensor which enable data logging function through wireless technology.

1.3.2 Objectives

The objectives of the research are:

(a) To design, construct and operate a rehabilitation process system mainly using gyroscope, accelerometer and tilt sensor.

(b) To interface the hardware and software parts of the system by embedding Android Apps with Arduino for compatibility process of the whole system.

(c) To evaluate the wireless data recording function of the designed prototype.

1.4 Scopes of The Project

This work presents the implementation of the orientation and position features via implementation of motion sensors.

- The outputs from these sensors were sent to a microcontroller. A computational algorithm is developed and programmed to the microcontroller to translate the raw linear data information and position in measurements of attitude and displacement.
- Both the raw and processed data are then transmitted wirelessly to a computer via radio frequency. The information was then used as input to a custom virtual simulation for further motion analysis.
- To propose a proper way of documenting the rehabilitation activities via the developed low-cost MEMs that also speed up the rehabilitation process of a post stroke patients.

1.5 Structure of The Thesis

This project report has been structured and organised into five chapters as follows:

Chapter 1 explains briefly about the introduction, problem statement, aim and objectives, scopes of the project, and the organisational of the project report.

Chapter 2 comprises of literature review from the past works, the related technology and hardware comparisons that are related to the project.

Chapter 3 describes the project methodology that includes system construction elements, hardware overview, software overview, the prototype and the design application overview of the project.

Chapter 4 presents the experimental results in terms of data and graphs, analysis and discussion obtained from the project.

Chapter 5 highlights the conclusions and recommendations for future works.

1.6 Research Achievements and Contributions

1.6.1 List of Publications

The research described in this thesis has led to the following presentations and publications:

a. S. Safyzan, A. B. Badri and M. Mahadi Abdul Jamil. (2013). Exploitation of Accelerometer for Rehabilitation Process. *IEEE International Conference on Control System, Computing and Engineering*. Penang.

b. Safyzan Salim and M. Mahadi Abdul Jamil. (2014). Monitoring of Rehabilitation Process Via Gyro and Accelerometer. *International Colloquium on Sport Science, Exercise, Engineering and Technology*. Penang.

c. Safyzan Salim, Wan Nurshazwani Wan Zakaria and M. Mahadi Abdul Jamil. (2014). Integration of Tilt Sensors as a Device for Monitoring Rehabilitation Process. *IEEE International Conference on Control System, Computing and Engineering*. Penang.

d. Safyzan Salim, Wan Nurshazwani Wan Zakaria and M. Mahadi Abdul Jamil. (2015). A Pilot Study of Embedding Android Apps with Arduino for Monitoring Rehabilitation Process. *6th International Conference on Information Science & Applications*. Phuket.

1.6.2 Grant

Project Title: Design and Development of Motion Analysis System for Medical Sport Technology
Type: Product Development Grant (GPP)
Amount: RM30,000.00
Duration: 12 Months
Date Awarded: 17 April 2013
Completed: 30 January 2014
Grant Reference: UTMH/PPI/600-5/1/14 Jld 3 (75)

1.6.3 List of Awards

a. Anugerah Kualiti dan Inovasi Kategori Inovasi Perkhimatan Awam (Teknikal) 2012,
Kementerian Kemajuan Luar Bandar dan Wilayah, Kuala Lumpur
Development of Artificial Hand Gripper for Rehabilitation by Using Microcontroller System

b. Pertandingan Rekacipta & Inovasi MARA Ke-10 Tahun 2012
MARA Japan Industrial Institute Beranang, Selangor:
(i) *Development of Smart Glove as An Assistive Device*
Gold
(ii) *Exploitation of Accelerometer for Rehabilitation Process*
Silver

c. 23rd International Invention, Innovation & Technology Exhibition 2012,
KLCC Kuala Lumpur:
(i) *Development of Smart Glove as An Assistive Device*
Gold
(ii) *Development of Circuit Breaker for Medical Instrumentation by Using Wired Monitoring System*
Gold

d. Malaysian Technology Expo 2012
PWTC Kuala Lumpur

Development of Artificial Hand Gripper for Rehabilitation by Using Microcontroller System

Silver

e. 24th International Invention, Innovation & Technology Exhibition 2013,
KLCC Kuala Lumpur
Design of Biomechatronic Artificial Arm for Telemedicine Application
Gold

f. Malaysian Technology Expo 2013,
PWTC Kuala Lumpur
Biomechatronics Design of Artificial Arm
Silver

g. UTeM Invention, Innovation and Technical Expo 2013
Universiti Teknikal Malaysia Melaka
Biomechatronic Design of Artificial Hand Gripper System for Rehabilitation Monitoring
Gold

h. 25th International Invention, Innovation & Technology Exhibition 2014
KLCC Kuala Lumpur
Smart Glove for Rehabilitation Using Telemedicine
Gold

i. Malaysian Technology Expo 2015
PWTC Kuala Lumpur
A Study of Motion Analysis in Sports Biomechanics
Bronze

j. 25th International Invention, Innovation & Technology Exhibition 2013
KLCC Kuala Lumpur
(i) *Monitoring of Rehabilitation Process Via Motion Analysis*
Silver

1.6.4 Patent

Safyzan Salim (2014). *Athlete Wearable Device Monitoring System*. PI 2014703286

REFERENCES

Aho K, Harmsen P, Hatano S, Marquardsen J, Smirnov V, Strasser T. Cerebrovascular Disease in the Community: Results of a WHO Collaborative Study. *Bull WHO.* 1980; 58: 113– 30.

Akyildiz, I. F., Su, W., Sankarasubramaniam, Y. & Cayirci, E. Wireless Sensor Networks: A survey. Computer Networks. 2002. 38(4): 93 – 422.

Allison L. Hall. *Method For The Acquisition Of Arm Movement Data Using Accelerometers*. Degree Thesis, Massachusetts Institute of Technology; June 2005.

Anuar H.M., Fadzil F., Ahmad N., Abd Ghani N. & Sallehuddin M.S. (2012). *Urut Melayu for Post-stroke Patients: A Qualitative Study*. Retrieved from http://www.nccr.gov.my/view_file.cfm?fileid =25

Arduino (2017). Home. Retrieved from http://www.arduino.cc/

Barris, Sian & Button, Chris. A Review of Vision-Based Motion Analysis in Sport. Sports Medicine (Auckland, N.Z.). 2008. 38: 1025 – 1043. 10.2165/00007256-200838120-00006.

Brian Barkley Graham. Using an Accelerometer Sensor to Measure Human Hand Motion. Master Thesis. Massachusetts Institute of Technology; 2000.

Chen Y, Baran M, Sundaram H & Rikakis T., A Low Cost, Adaptive Mixed Reality System For Home-Based Stroke Rehabilitation. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. 2011.

Christine K. Cassel. *Geriatric Medicine:* An Evidence-based Approach*. 4th Ed. New York*: Springer Press. 2003.

Carlos Ferreira, Vânia Guimarães, António Santos & Inês Sousa. Gamification of stroke rehabilitation exercises using a smartphone. Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare. May 20 - 23, 2014. Germany. 2014. pp. 282 – 285.

Chu, Wei-Ta & Situmeang, Samuel (2017). Badminton Video Analysis based on Spatiotemporal and Stroke Features. pp. 448-451. Retrieved from 10.1145/3078971.3079032.

Chuan-Jun Su, Chang-Yu Chiang, Jing-Yan Huang, Kinect-enabled Home-based Rehabilitation System using Dynamic Time Warping and Fuzzy Logic. *Applied Soft Computing*. 2014. 22: 652 – 666.

Dawn A. Marcus. Chronic Pain: A Primary Care Guide to Practical Management. *Humana Press*. 2008.

Derick T. Wade & Richard Langton. Hospital Admission For Acute Stroke: Who, For How Long, and to What Effect?. *Journal of Epidemiology and Community Health*. 1985. 39: 347 – 352

Digi International. (2012). *Zigbee RF Modules XBEE2, XBEEPRO2, PRO S2B*. Retrieved from www.digi.com/resources/documentation/digidocs/pdfs/.pdf

Emmanuel Tsekleves, Ioannis Paraskevopoulos, Alyson Warland, & Cherry Kilbride (2014). Personalised Stroke Rehabilitation Intervention using Open Source 3D Software and The Wii Remote Plus. Retrieved from doi: 10.3109/17483107.2014.981874

Erasmus, F. B., David, R. P. Physical Condition, Activity Pattern and Environment as Factors in Falls by Adult Care Facility Residents. Academy of Physical Medicine & Rehabilitation. 1993. 74: 627 – 630.

Furie B., Furie B.C. Mechanisms of Thrombus Formation. *New England Journal of Medicine.* 2008. 359(9): 938 – 949.

F. Knight, James & W. Bristow, Huw & Anastopoulou, Stamatina & Baber, Chris & Schwirtz, Anthony & Arvanitis, Theodoros. Uses of accelerometer data collected from a wearable system. *Personal and Ubiquitous Computing*. 2007. pp. 117 – 132.

Gerlach-Meyer U. E. Micromachined Capacitive Accelerometer. *Sensors and Actuators A: Physical*. 1991. 27(1): 555 – 558.

Grammaticos Philip & Diamantis Aristidis. Useful Known and Unknown Views of The Father of Modern Medicine, Hippocrates and His Teacher Democritus. *Hellenic Journal of Nuclear Medicine*. 2008. pp. 2 – 4.

Handin R.I. Chapter 53: bleeding and thrombosis. In Kasper DL, Braunwald E, Fauci AS, et al. *Harrison's Principles of Internal Medicine* (16th Ed.). New York, NY: McGraw-Hill. 2005

Hossein M. H., Maryam K., Lucy D., Steven C. C. & Cristina V. L. A Spatial Augmented Reality Rehab System for Post-Stroke Hand Rehabilitation. *IOS Press*. 2013. pp. 279 – 285.

Hutan Ashrafian. (2010), *Familial Stroke 2700 Ago*, 2010, Retrived on 28 September, 2017, from doi: 10.1161/STROKEAHA.109.573170.

H. Zhou, H. Hu. *Human Motion Rracking for Rehabilitation-A Rrvey.* Biomedical Signal Processing and Control 3. 2018. pp. 1-18.

H. Zhou, H. Hu (2004). *A Survey-human Movement Tracking and Stroke Rehabilitation*. Tech. rep., CSM-420, Department of Computer Science, University of Essex, UK, 2004.

H. Zheng, R. J. Davies, N. D. Black, Web-based Monitoring System for Home-based Rehabilitation with Stroke Patients, *Computer-Based Medical Systems*. 2005, pp. 419 – 424.

H.M.Dalal, P.H.Evans, J.L.Campbell, R.S.Taylor, A.Watt, K.L.Q.Read, A.J.Mourant, J.Wingham, D.R. Thompson and D.J. Pereira Gray (2007). Home-based Versus Hospital-based Rehabilitation After Myocardial Infarction: A Randomized Trial with Preference Arms-Cornwall Heart Attack Rehabilitation Management Study (CHARMS). *International Journal of Cardiology*, 2007. 119(2): 202 – 211.

Jamal J.A., Malay Traditional Medicine an Overview of Scientific and Technological Progress. *Asia-Pacific Tech Monitor*. 2007, 23: 37 – 49.

Jae-Myung Yoo & Yong-Myung Ahn., A Study on A Sensing System For Artificial Arm's Control, *SICE-ICASE International Joint Conference*. Busan. 2006.

Jang, W. S. & Skibniewski, M. J. A Wireless Network System for Automated Tracking of Construction Materials on Project Sites. *Journal of Civil Engineering and Management*. 2008. 14(1): 11 – 19.

Jesse E. Thompson. (1996). *The Evolution of Surgery For The Treatment And Prevention of Stroke. The Willis Lecture.* Retrived on 28 September, 2017, from doi: 10.1161/01.str.27.8.1427.

Joel A. DeLisa, Bruce M. Gans, William L. Bockenek and Walter R.Fontera. *Physical Medicine and Rehabilitation: Principles and Practice*. 4th Ed. JAMA: Lippincott Williams & Wilkins Press. 2004.

Kadar, P. ZigBee controls the household appliances. *International Conference on Intelligent Engineering Systems*. 2009, pp. 189 – 192.

Kamiyama, Takashi & Kameda, Yoshinari & Ohta, Yuichi & Kitahara, Itaru. (2017). Improvement of Badminton-Player Tracking Applying Image Pixel Compensation. ITE Transactions on Media Technology and Applications. 5: 36-41. Retrieved from 10.3169/mta.5.36.

Keat Wei Loo, Siew Hua Gan. Burden of stroke in Malaysia. *International Journal of Stroke*. 2012. 7(2): 165-167.

Kristen L. Mauk. *Gerontological Nursing: Competencies for Care.* 2nd Ed. Massachusetts: Jones & Bartlett Learning. 2009.

Kate Jolly, Rod S. Taylor, Gregory Y. H. Lip and Andrew Stevens. *Home-based cardiac rehabilitation compared with centre-based rehabilitation and usual care: A systematic review and meta-analysis*. International Journal of Cardiology. 2006. 111(3): 343 – 351.

K. Simone, L.& Elovic, E &. Kalambur, U. & Kamper, Derek. A Low Cost Method to Measure Finger Flexion in Individuals with Reduced Hand and Finger Range of Motion. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. 2004. pp. 4791 – 4794.

Lars Nyberg and Yngve Gustafson, Patient Falls in Stroke Rehabilitation. *Stroke*. 1995. 26(5): 838 – 842.

Naghshineh S., Ameri G., Zereshki, M., & Krishnan, D.S. *Human Motion Capture using TriAxial Accelerometers*. 2009.

Mike Hughey. (2011). *Nursing Fundamentals I.* http://www.brooksidepress.org/Products/Nursing_Fundamentals_1/lesson_5_Section_1.htm

Mion L.C., Gregor S., Buettner M., Chwirchack D., Lee O. & Paras W. Falls in the Rehabilitation Setting: Incidence and Characteristics. Rehabilitation Nursing. 1989. 14: 17 – 22.

Nicola D'Apuzo & Harvey Mitchell Medical Appilcations. In: Zhilin Li, Jun Chen & Emmanuel Baltsavias. *Advances in Photogrammetry, Remote Sensing and Spatial Information*. CRC Press. 2008. pp. 425 – 436.

Norrefalk, Jan-Rickard. How Do We Define Multidisciplinary Rehabilitation?. *Journal of Rehabilitation Medicine*. 2003. 35: 100 – 101.

Oliver Amft et al, "Sensing Muscle Activities with Body-Worn Sensors", *International Workshop on Wearable and Implantable Body Sensor Networks*, IEEE Computer Society. 2006.

Patrick D.L., Starks H.E., Cain K.C., Uhlmann R.F. & Pearlman R.A.. Measuring preferences for health states worse than death. *Medical Decision Making*. 1994. 14:9 – 18.

Pearlman, R.A. & C. Cain, K. & L. Patrick, D. & Appelbaum-Maizel, M. & Starks, Helene & Jecker, Nancy & F. Uhlmann, R. Insights Pertaining to Patient Assessments of States Worse Than Death. *Journal of Clinical Ethics*. 1993. 4: 33 – 41.

Peggy A. Houglum. Therapeutic Exercise for Musculoskeletal Injuries. *Human Kinetics Publisher*. 2010.

Pueo, Basilio & Jimenez-Olmedo, Jose. Application of Motion Capture Technology for Sport Performance Analysis. *Retos: nuevas tendencias en educación física, deporte y recreación*. 2017. pp. 241 – 247.

Pierre J. Vinken, George W. Bruyn, Harold L. Klawans, James F.Toole. *Vascular Diseases.* Part 3, Elsevier Health Sciences, 1989, pp. 234 – 239

Rahman A.S., & Al-Jumaily A. Design and Development of a Bilateral Therapeutic Hand Device for Stroke Rehabilitation. *International Journal of Advanced Robotic Systems*. Elsevier. 2013. pp. 1028 – 1034

R.S. Taylor, A. Watt, H.M. Dalal, P.H. Evans, J.L. Campbell, K.L.Q. Read, A.J. Murant, J. Wingham, D.R. Thompson, D.J. Pereira Gray. Home-based Cardiac Rehabilitation Versus Hospital-based Rehabilitation: A Cost Effectiveness Analysis *Int. J. Cardiol*. 2007. 119(2): 196 – 201.

Roy S., Cheng M., Chang S., Moore J., De Luca G., Nawab S. &De Luca C.. A Combined sEMG and Accelerometer System for Monitoring Functional Activity in Stroke. *IEEE Transactions On Neural System And Rehabilitation Engineering.* 2009. 17(6).

Razali Tomari, Wan Nurshazwani Wan Zakaria and Muhammad Mahadi Abdul Jamil Towards Socially Acceptable Assistive Wheelchair System by Monitoring User and People Around. *Introduction To Biomedical Engineering Research Projects And Case Studies*. Universiti Tun Hussein Onn Malaysia 2015

Ruiz-Garcia, L., Barreiro, P., Robla, J. I. Performance of ZigBee-based Wireless Sensor Nodes for Real-time Monitoring of Fruit Logistics. *Journal of Food*

Engineering. 2008. 87(3): 405 – 415.

R. Ambar, M. S. Ahmad, A. M. Mohd Ali and M. M. Abdul Jamil, "Arduino Based Arm Rehabilitation Assistive Device," Journal of Engineering Technology, vol. 7, 2011, pp. 5-13.

R. Chapman et al. (1999). *A Motorless Artificial Limb and its Control Architecture*. In Proc. IEEE Canadian Conference on Electrical and Computer Engineering Show Conference Center, Edmonton, Canada; May 9-12, 1999.

Ryan Fitzhenry. *Design and Develop Virtual Reality Games Utilising the "Anti-gravity" Arm Support for Stroke Rehabilitation Therapy*. Degree Thesis. University of Southern Queensland, Australia; 2009.

Safyzan Salim and M. Mahadi Abdul Jamil, "Monitoring of Rehabilitation Process Via Gyro and Accelerometer Sensor", International Colloquium on Sports Science, Exercise, Engineering & Technology, Apr 2014

Sakaguchi, T & Kanamori, T & Katayose, Haruhiro & Sato, K & Inokuchi, Seiji. Human Motion Capture by Integrating Gyroscopes and Accelerometers. *International Conference on Multisensor Fusion and Integration for Intelligent Systems*. 1997. pp. 470 – 475.

Sam Naghshineh, Golafsoun Ameri, Mazdak Zereshki (2009). *Human Motion Capture using Tri-Axial accelerometers*. Retrieved from https://pdfs.semanticscholar.org/0953/5749f138d974d670e2ae9e1cf741a612a19b.pdf?_ga=2.167573310.1450650838.1546669504-923641578.1546669504

Schillar F. Concepts of Stroke Before and After Virchow. *Medical History*. 1970. 14(2): 115 – 131.

Serdar Ates, Claudia J. W. & Haarman Arno H. A. Stienen. SCRIPT passive orthosis: design of interactive hand and wrist exoskeleton for rehabilitation at home after stroke. *Autonomous Robots*. US. Springer. 2017. pp. 711 – 723

Schonewetter R.S., Walker R.M., Kramer D.R., Robinson B.E. Resuscitation Decision Making in the Elderly: the Value of Outcome Data. *Journal of General Internal Medicine*. 1993. 8(6): 295 – 300.

Sheikh K, Meade T.W., Brennan P.J., Goldenberg E, Smith D.S. Intensive Rehabilitation After Stroke: Service Implications. *Community Medicine* 1981. 3: 210 – 6.

Takashi Sakaguchi et al. (1996). *Human Motion Capture by Integrating Gyroscopes and Accelerometers.* International Conference on Multisensor Fusion and Integration for Intelligent Systems". 1996.

Terent A. Medico-social consequences and direct costs of stroke in a Swedish community. Scand J Rehab Med 1983; 15: 165-71. 'Gibson CJ. Epidemiology and patterns of care of stroke patients. Arch Phys Med Rehabil 1974; 55: 898 – 903.

Thompson, Trevor & Steffert, Tony & Ros, Tomas & Leach, Joseph & Gruzelier, John. (2008). EEG Applications for Sport and Performance. *Methods* (San Diego, Calif.). 45. 279-88. 10.1016/j.ymeth.2008.07.006.

Vellas, B., Cayla, F., Bocquet, H., de Pemille, F. & Albarede, J.L. Prospective Study of Restriction of Activity in Old People After Falls. Age Ageing. 1987. 16: 189 – 193.

Wood-Daupnee, S.S.Shapiro, E.Bass, C.Fletcher, P.Georges, V.Hensby and B.Mendelsohn *A randomized trial of team care following stroke*. Stroke. 1984. 15: 864 – 872.

World-stroke (2016). *Facts and Figures about Stroke*. Retrieved from https://www.world-stroke.org/component/content/article/16-forpatients/84-facts-and-figures-about-stroke

Y.J. Chang, S.F. Chen, A.F. Chuang. A Kinect-based System for Physical Rehabilitation: A Pilot Study for Young Adults with Motor Disabilities *Research in Development Disabilities*. Elsevier. 2011. 32(6): 2566 – 2570.

Wu B., Liu M., Liu H., Li W., Tan S., Zhang S. & Fang Y. (2007). Meta-analysis of traditional Chinese patent medicine for ischemic stroke. Retrieved from doi: 10.1161/STROKEAHA.106.473163

Zhang, Cheng & Yang, Fan & Li, Gang & Zhai, Qiang & Jiang, Yi & Xuan, Dong. MV-Sports: A Motion and Vision Sensor Integration-Based Sports Analysis System. 2018. pp.1070-1078. 10.1109/INFOCOM.2018.8485910.

Zheng Huiru & Davies, Richard & Black, Norman. Web-Based Monitoring System for Home-Based Rehabilitation with Stroke Patients. *2012 25th IEEE International Symposium on Computer-Based Medical Systems*. 2005. pp. 419 – 424.